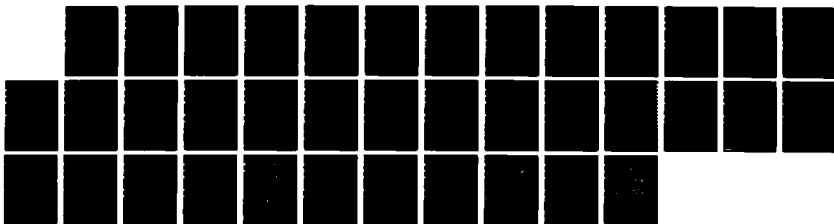


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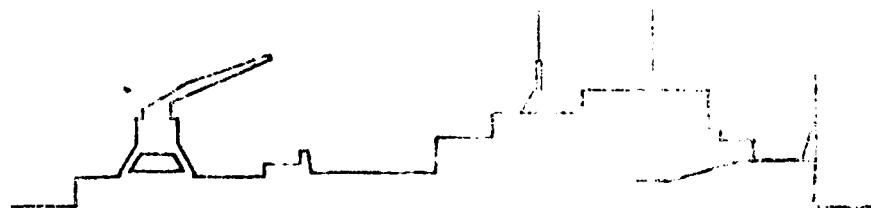
DESIGN ANALYSIS OF
TYPHOON MOORINGS FOR
WALLACE AIR STATION, P.I.

by

William N. Seelig, P.E.

FPO-1-85(54)

December 1985



Ocean Engineering

CHESAPEAKE DIVISION
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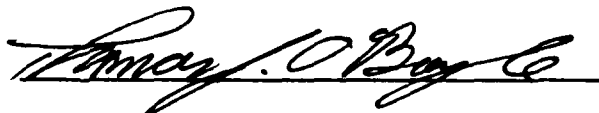
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SECURITY CLASSIFICATION OF THIS PAGE

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REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION

Unclassified

1b. RESTRICTIVE MARKINGS

2a. SECURITY CLASSIFICATION AUTHORITY

3. DISTRIBUTION AVAILABILITY OF REPORT
Approved for public release;
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2b. DECLASSIFICATION/DOWNGRADING SCHEDULE

4. PERFORMING ORGANIZATION REPORT NUMBER
FPO-1-85(54)

5. MONITORING ORGANIZATION REPORT NUMBER

6a. NAME OF PERFORM. ORG.
Ocean Engineering
& Construction
Project Office
CHESNAVFACEGCOM

6b. OFFICE SYMBOL

7a. NAME OF MONITORING ORGANIZATION

6c. ADDRESS (City, State, and Zip Code)
BLDG. 212, Washington Navy Yard
Washington, D.C. 20374-2121

7b. ADDRESS (City, State, and Zip Code)

8a. NAME OF FUNDING ORG.

8b. OFFICE SYMBOL

9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER

8c. ADDRESS (City, State & Zip)

10. SOURCE OF FUNDING NUMBERS

PROGRAM	PROJECT	TASK	WORK UNIT
ELEMENT #	#	#	ACCESS #

11. TITLE (Including Security Classification)

Design Analysis of Typhoon Moorings for Wallace Air Station, P.I.

12. PERSONAL AUTHOR(S)

William N. Seelig

13a. TYPE OF REPORT

Final

13b. TIME COVERED

FROM 850901 TO 851226

14. DATE OF REPORT (YYMMDD)

851226

15. PAGES

34

16. SUPPLEMENTARY NOTATION

COSATI CODES		
FIELD	GROUP	SUB-GROUP

18. SUBJECT TERMS (Continue on reverse if necessary)
Mooring systems, Ship moorings, typhoon moorings, Wallace Air Station, P.I.

19. ABSTRACT (Continue on reverse if necessary & identify by block number)
Design of four identical typhoon moorings for Wallace Air Station, San Fernando, Philippines are presented. The purpose of these moorings is to restrain 110-foot and smaller target retrieval vessels. The design considers static and dynamic effects of extreme winds, currents and waves at the site. (Continued)

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT
UNCLASS/UNLIMITED X SAME AS RPT. DTIC

21. ABSTRACT SECURITY CLASSIFICATION
Unclassified

22a. NAME OF RESPONSIBLE INDIVIDUAL
William N. Seelig

22b. TELEPHONE
202-433-3881

22c. OFFICE SYMBOL
FPO-1EA2

DD FORM 1473, 84MAR

SECURITY CLASSIFICATION OF THIS PAGE

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The recommended design is a modified Fleet Mooring design customized for the site with special emphasis on dynamic effects. The mooring legs and riser are made of 2" chain and the buoy is a standard 5' x 9.5' diameter can. Anchors are 13 kip stockless modified with stabilizers and with flukes fixed for sand. A 10,000 sinker and double 150-foot long 2" diameter nylon hawsers are used to "soften" the mooring thereby reducing dynamic loads.

The recommended design has excellent load/deflection characteristics, uses available Fleet Mooring materials in the area, will be easy to install, maintain and/or relocate.

EXECUTIVE SUMMARY

Design of four identical typhoon moorings for Wallace Air Station, San Fernando, Philippines are presented. The purpose of these moorings is to restrain 110-foot and smaller target retrieval vessels. The design considers static and dynamic effects of extreme winds, currents and waves at the site.

The recommended design is a modified Fleet Mooring design customized for the site with special emphasis on dynamic effects. The mooring legs and riser are made of 2" chain and the buoy is a standard 5' x 9.5' diameter can. Anchors are 13 kip stockless modified with stabilizers and with flukes fixed for sand. A 10,000 sinker and double 150-foot long 2" diameter nylon hawers are used to "soften" the mooring thereby reducing dynamic loads.

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DESIGN ANALYSIS OF TYPHOON MOORINGS
WALLACE AIR STATION
PHILIPPINES

by

William N. Seelig, P.E.

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**DESIGN ANALYSIS OF HURRICANE MOORINGS
WALLACE AIR STATION
PHILIPPINES**

by

William N. Seelig, P.E.

Introduction

Four moorings are required at the joint USAF/Navy Drone Recovery Facility at Wallace Air Station, Philippines (reference 1). There are currently no moorings or safe piers that can hold these vessels during typhoons or extreme storms. Figure 1 shows the proposed mooring locations.

Wooden vessels of 65 and 85 foot lengths are currently being used at the facility (reference 2). New aluminum boats of 110-foot length are being planned for the facility to replace the older vessels (reference 3). The new boats are now in the design stage and should be built in 1987. Moorings are designed to be used with either present or planned vessels.

Design Considerations

This design analysis is made using the following approach: mooring materials should come from the local Fleet Mooring materials inventory, moorings will be installed by the Ship Repair Facility at Subic Bay, all moorings will be able to accommodate one of the 110-foot vessels, CHESNAVFACENGCOM will provide the design and installation quality assurance.

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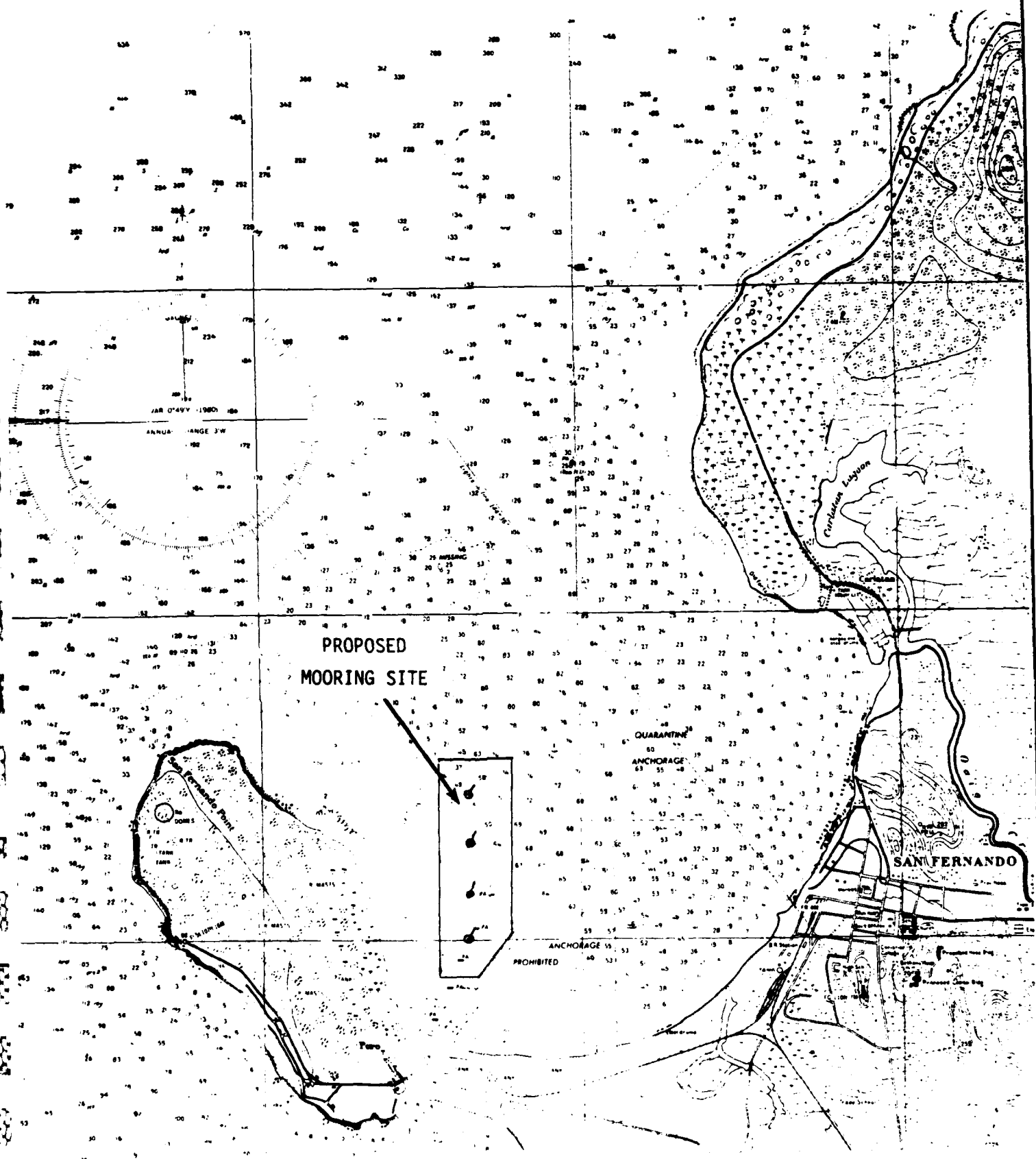


Figure 1. PROPOSED MOORING LOCATIONS

Design Criteria

Much of the background information used in this design (see reference 2 for a compilation of information available for the site) was obtained during a site visit made by FPO-1C8 in January 1985. Table 1 summarizes criteria employed in this design analysis. Specific notes on various design criteria are given below.

Vessels

NAVSEA (PMS Codes 3002 and 30022) provided information on the 110-foot vessels now being designed (reference 3, see Appendix A for a summary of vessel characteristics).

Wind

NAVFAC Design Manual 26 (reference 4) gives the highest observed winds for the Philippines as 191 ft/sec (130 mph) for 30-second duration wind. This wind value is tentatively selected for design and extra safety factors added to allow mooring use in higher winds. Additional statistics of extreme winds are available in reference 5.

Current

The highest measured current during non-storm conditions is 0.5 feet/sec for the site (reference 5). A design current of 3.0 feet/sec is conservatively selected for design.

Waves

The highest hindcast extreme typhoon waves are predicted to have a maximum wave height of 9.6 feet (reference 5). These predicted conditions include the effects of refraction and diffraction. See Appendix B for detailed information on typhoon waves.

Geotechnical

A boring near the proposed mooring site shows a 50-foot thick layer of sand with some mixed shell (reference 5).

Table 1.

TYPHOON MOORING DESIGN CRITERIA
Wallace Air Station, P.I.

<u>ITEM</u>	<u>CONDITION</u>
<u>VESSELS</u>	110-Foot Recovery Vessels
<u>ENVIRONMENT</u>	
wind (30-sec)	130 mph (max. observed)
current	3 ft/sec
max. tide+surge	6 ft
water depth	56 ft max. total
seafloor	50 ft thick sand layer
<u>DESIGN LOADS</u>	
quasi-static	9.6 kips
dynamic	28 kips
<u>MOORING COMPONENTS</u>	
	F.S. Static Dynamic
Buoy 5' x 9.5' dia.	Can - -
Chain	2" chain 33 11
Anchor with stab.	13 kip stockless 9 3
Hawser	double 2" nylon 14 5
<u>MOORING CHARACTERISTICS</u>	
Watch circle radius	315 ft at vessel stern
Buoy spacing	900 ft

Harbor Geometry

Available mooring space limits the buoy spacing to 900 feet (see Figure 1).

One-hundred foot high bluffs to the west, south, east and northeast will provide some sheltering of moored vessels (Figure 1). The worst condition will be a wind from the northwest, which will have winds coming directly from the sea (no land blockage) and produce design waves (Table 1). This condition is used for design.

Storm Surge

Storm surge values are unknown for the area. A value of 2 meters (feet) is taken as representative for hurricane conditions (reference 6).

Mooring Design Loads

Static and dynamic loads of the vessel on the mooring are examined in this section as discussed below.

"Quasi Static" Load

The 30-second design wind speed of 130 mph and current produce single point mooring line tensions shown in the upper curve of Figure 2 (see Appendix A for calculation details). The "equilibrium" point where the moment (lower curve in Figure 2) is zero is defined as the quasi static load. This load is 9.6 kips for the design vessel (Point "A" on Figure 2).

Ship Yaw Load

A vessel in a single point mooring will fishtail (Figure 3). A 30 degree maximum vessel yaw is assumed for design because this vessel/mooring has a steep restoring moment curve (lower curve of Figure 2). The mooring line tension increases as the vessel yaws, so a design load of 18 kips is produced (Point "B" on Figure 2).

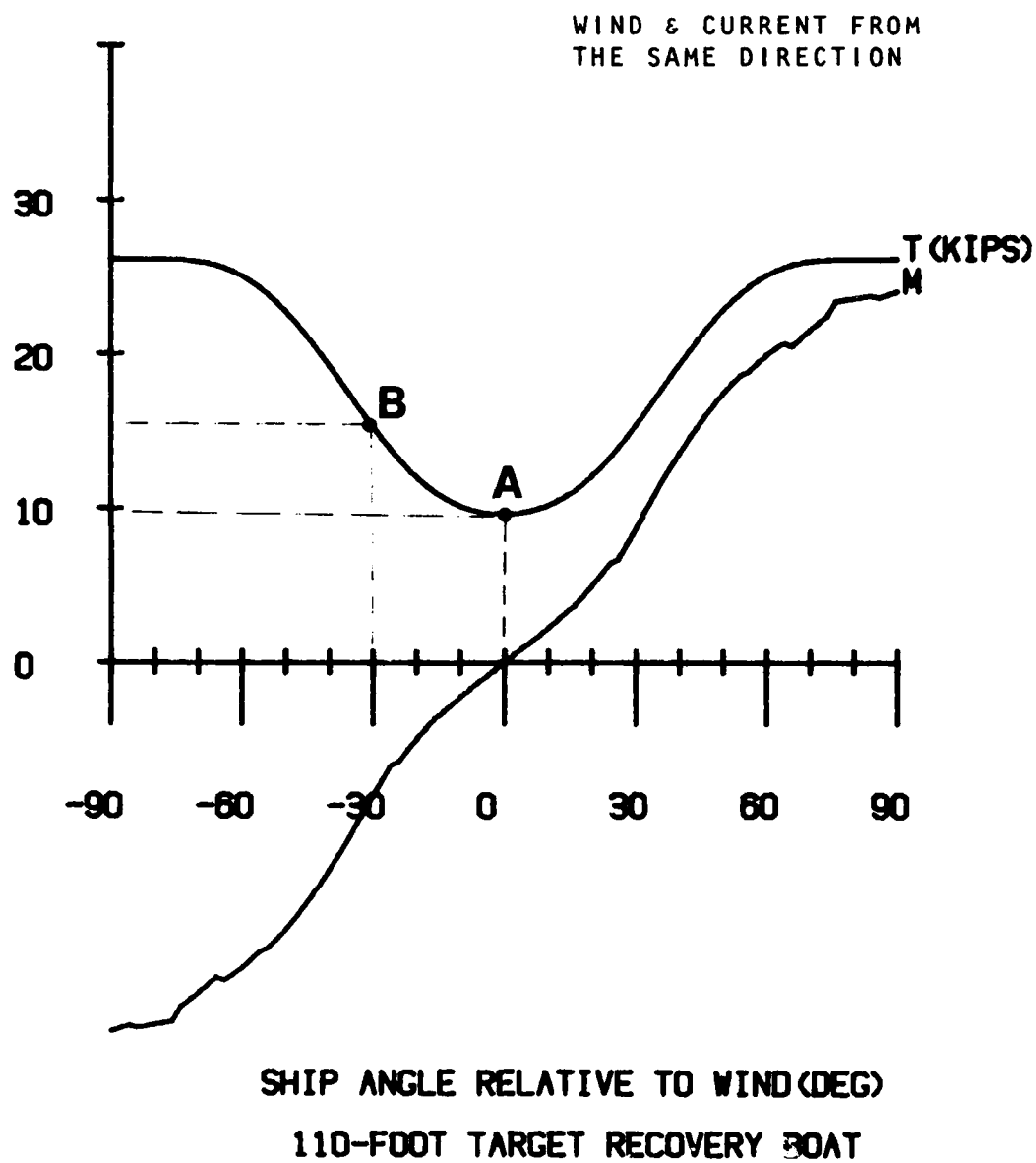


Figure 2. "QUASI-STATIC" SINGLE POINT MOORING ANALYSIS

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PROJECT: _____

Naval Facilities Engineering Command

NDW

Station: _____

DISCIPLINE

E S R: _____

Contract: _____

Calcs made by: W. Seelig

date: 12/14/84

Calculations for: "Fish Tailing"

Calcs ck'd by: A

date: _____

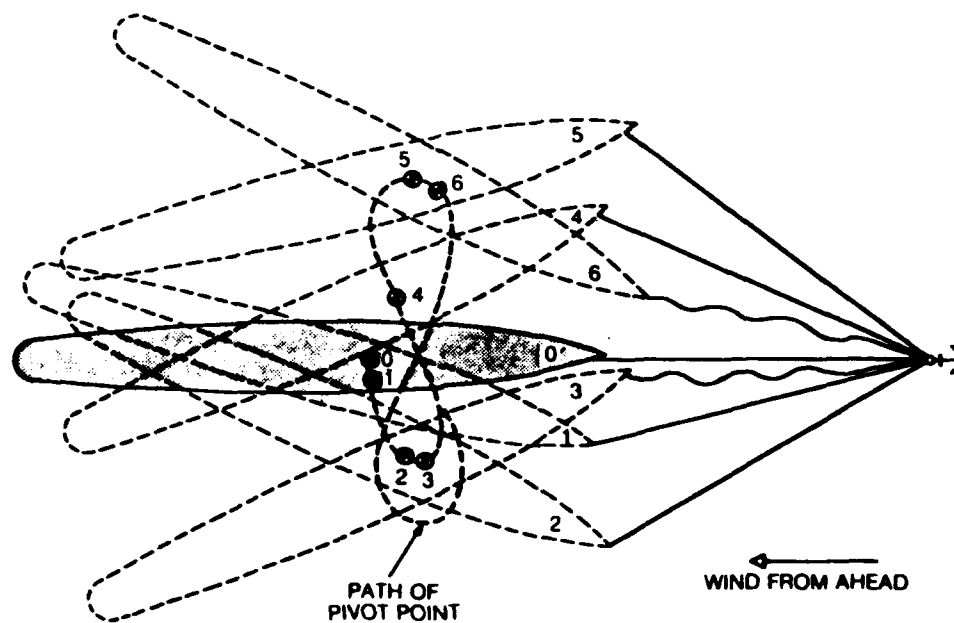


Figure 3. SHIP FISHTAILING

Dynamic Vessel Surge Due to Wind Gusts

Wind forcing on the vessel changes with time because the wind speed is a function of time. Typhoon winds have especially short duration and high speed wind gusts. A one-dimensional numerical dynamic time marching model of the vessel in surge was run using the mooring load/deflection curve (Figure 4). Predicted mooring hawser loads as a function of time are shown in Figure 5. The peak load is 20 kips due to wind gusts and other secondary effects. This is Point "A" on the mooring load/deflection curve (Figure 4).

Mooring Loads Due to Waves

The maximum design load in the mooring is found using the following procedure (recommended by API RP2, reference 6):

- a. Assume that the vessel is at the maximum surge position due to winds and currents (Point "A" on Figure 4).
- b. Assume that the maximum wave occurs with the vessel at Point "A" .
- c. Assume that the vessel surge is equal to the amplitude of the water wave particle motion. This is Point "B" on Figure 4 and corresponds to a maximum mooring load of 28 kips.

Mooring Design

Numerous mooring designs were evaluated and the final design (Figure 6) selected based on the following factors:

- a. The mooring acts as a shock absorber to minimize dynamic loads (see the load/deflection curve in Figure 4). This excellent energy absorption is due to the combined effects of sinker lifting, buoy submerging, riser catenary and nylon mooring line hawser stretch.

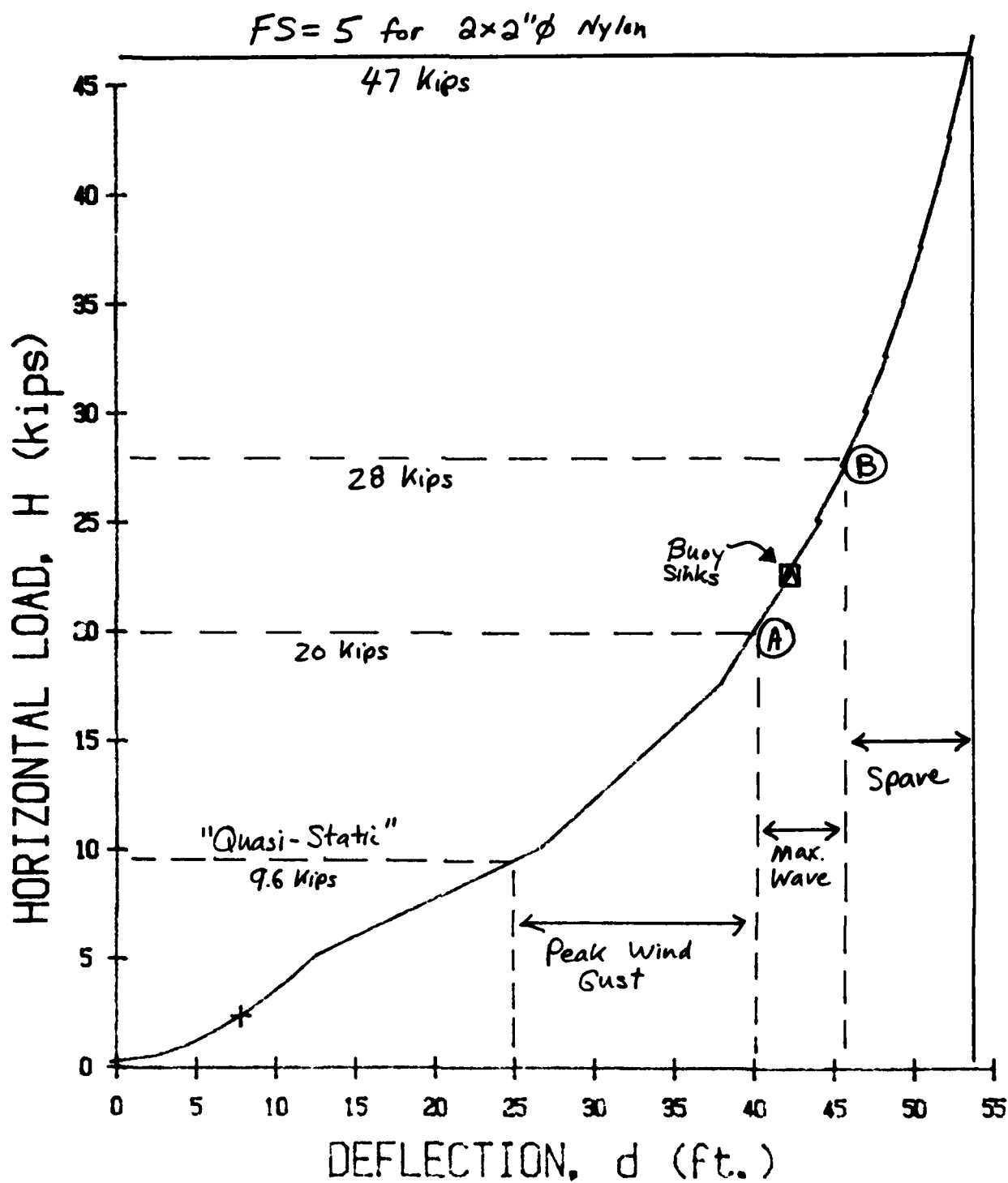
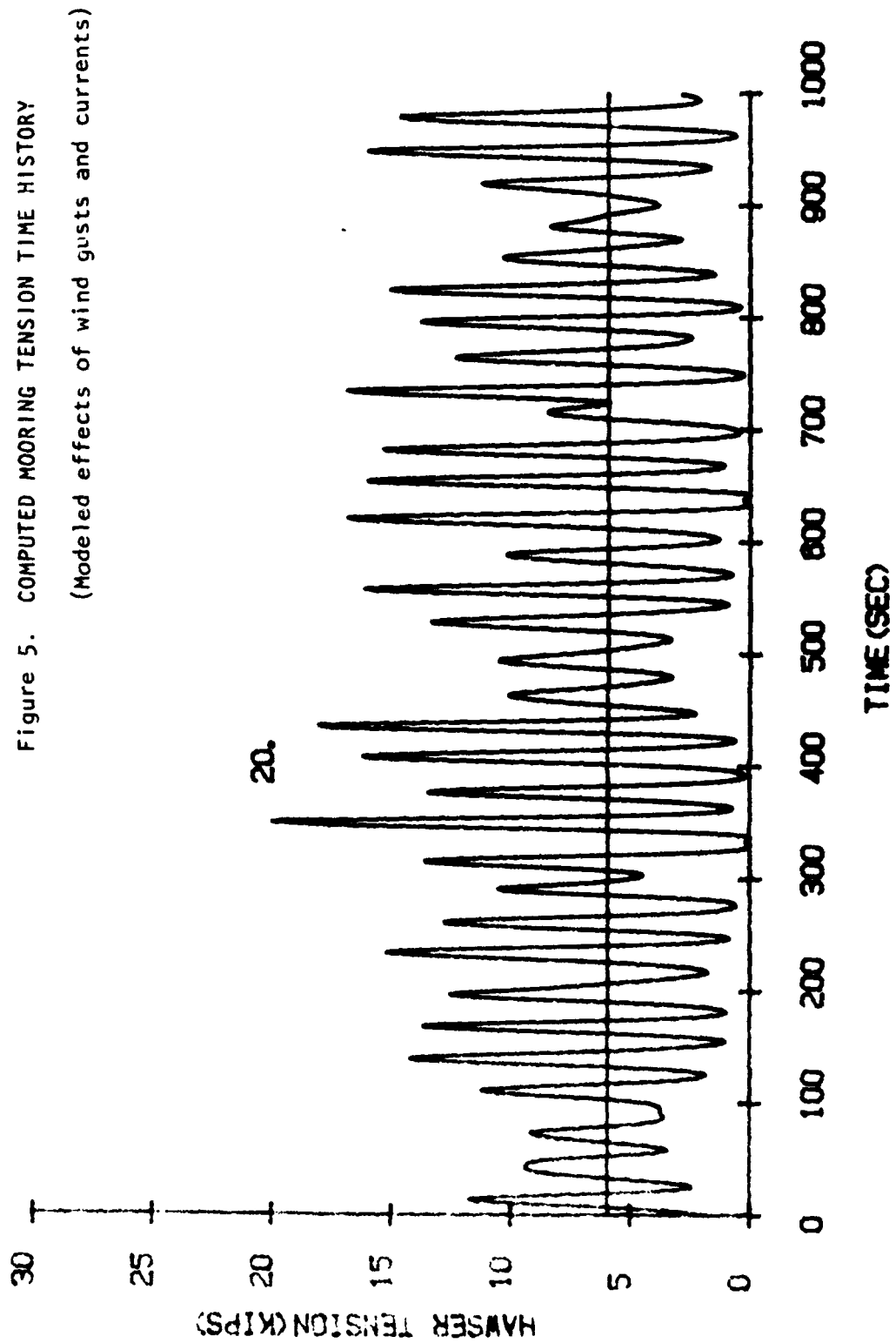


Figure 4. MOORING LOAD/DEFLECTION CURVE WITH NOTES

RESEARCH REPORT AT SEA/ERNA/NT-EXPENSE



b. Fleet Mooring inventory materials are used.

c. The moorings are easy to install and can be removed for maintenance and/or relocated.

A 13,000 pound stockless anchor is used for each mooring (see Appendix B for anchor selection). This anchor is 6 times larger than would be normally used for a Fleet Mooring. This provides extra safety for the typhoon moorings with one ground leg.

A 150-foot long double 2" diameter nylon mooring hawser is used to moor vessels to the buoy (see Appendix C for details).

SUMMARY

Analysis of the design and use of four typhoon moorings for Wallace Air Station, Philippines is presented in this report. These moorings are designed to be used by present boats at the site and 110-foot aluminum vessels planned to be delivered to the station in 1987.

REFERENCES

1. PACNAVFACENGCOM message 040308Z JUL 85.
2. MEMO by FPO-1C8, 26 Feb 85, CHESNAVFACENGCOM.
3. PHONECON with N. Adams (NAVSEA Code PMS 3002) at 202-692-8402.
4. NAVFAC D.M. 26.5, Fleet Moorings, June 1985.
5. Japan International Coop. Agency, "The Development Project of the Port of San Fernando, Philippines", Dec 1983.
6. API, "The Analysis of Spread Mooring Systems for Floating Drilling Units", API RP 21P, Jan. 1, 1984.
7. U.S. Army Corps of Engineers, Shore Protection Manual, 1984.

APPENDIX A.

VESSEL CHARACTERISTICS AND COMPUTED COEFFICIENTS

Information presented in this appendix includes calculations of the six dimensionless force coefficients due to wind and currents. Vessel characteristics are also presented and the maximum wave orbital particle amplitude is computed for the mooring site.

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Naval Facilities Engineering Command

NDW

DISCIPLINE

PROJECT: Mooring AnalysisStation: Wallops AFB

E S R: _____ Contract: _____

Calcs made by: W. Seelig date: 7/9/85Calcs ck'd by: [Signature] date: 7/19/85Calculations for: Mooring ForcesDesign Vessel 110' Target Recovery Vessel *Length = $110' \approx L_{OA} \approx L_{WL} = L$ Width $B \approx 24'$ Displacement = $D \approx 110$ Long TonsSide Area $A_y \approx 900 \text{ ft}^2$ End Area $A_e \approx 330 \text{ ft}^2$ Draft $T \approx 5.5'$ Water depth $\approx 50' = wd$ $h_s \approx 15'$ $A_s \approx 330 \text{ ft}^2$ $A_x \approx 330 \text{ ft}^2$ $h_{1/2} \approx 5'$ $A_{1/2} \approx 550 \text{ ft}^2$ $A_y = 900 \text{ ft}^2$

* Note: Vessel not yet built. The above dimensions are based on preliminary design data.

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$$F_{yw} = \frac{1}{2} (0.00237) V_w^2 A_y C_{yw} f_{yw} (Q_w) \quad \text{Eq (5-11)}$$

$$C_{yw} = 0.92 \left[\left(\frac{h_s}{33} \right)^{2/7} A_s + \left(\frac{h_H}{h_R} \right)^{2/7} A_H \right] / A_y \quad \begin{matrix} \text{Eq (5-12)} \\ \text{Eq (5-13)} \end{matrix}$$

$$= 0.92 \left[\left(\frac{15}{33} \right)^{2/7} 350 + \left(\frac{5}{33} \right)^{2/7} 550 \right] / 900$$

$$C_{yw} = 0.6135$$

$$F_{yw} = \frac{1}{2} (0.00237) V_w^2 (900) (0.6135) f_{yw} (Q_w)$$

$$F_{yw} = 0.554 V_w^2 f_{yw} (Q_w)$$

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Calculations for: _____

WIND LOADEND

$$F_{xw} = \frac{1}{2} \rho_a V_w^2 A_x C_{xw} f_{xw}(\theta_w) \quad Eq(5-16)$$

$$\text{Let } C_{xw} = 0.8 \text{ (conservative)} \quad Eq(5-21)$$

∴

$$F_{xw} = \frac{1}{2} (0.00257) (V_w^2) (330) (0.8) f_{xw}(\theta_w)$$

$$\underline{F_{xw} = 0.313 V_w^2 f_{xw}(\theta_w)}; \quad f_{xw}(\theta_w) \text{ from } Eq(5-23) \\ \text{with } \theta_{w2} = 80^\circ \text{ (Table 12)}$$

MOMENT

$$M_{xw} = \frac{1}{2} (0.00257) V_w^2 A_x L C_{mx} f_{xw}(\theta_w) \quad Eq(5-29)$$

$$= \frac{1}{2} (0.00257) V_w^2 (900) (110) C_{mx} f_{xw}(\theta_w)$$

$$\underline{M_{xw} = 117 V_w^2 C_{mx} f_{xw}(\theta_w)}$$

$$C_{mx} = 1.0 \quad \text{for } 50^\circ \text{ to } 110^\circ \text{ (Table 12)}$$

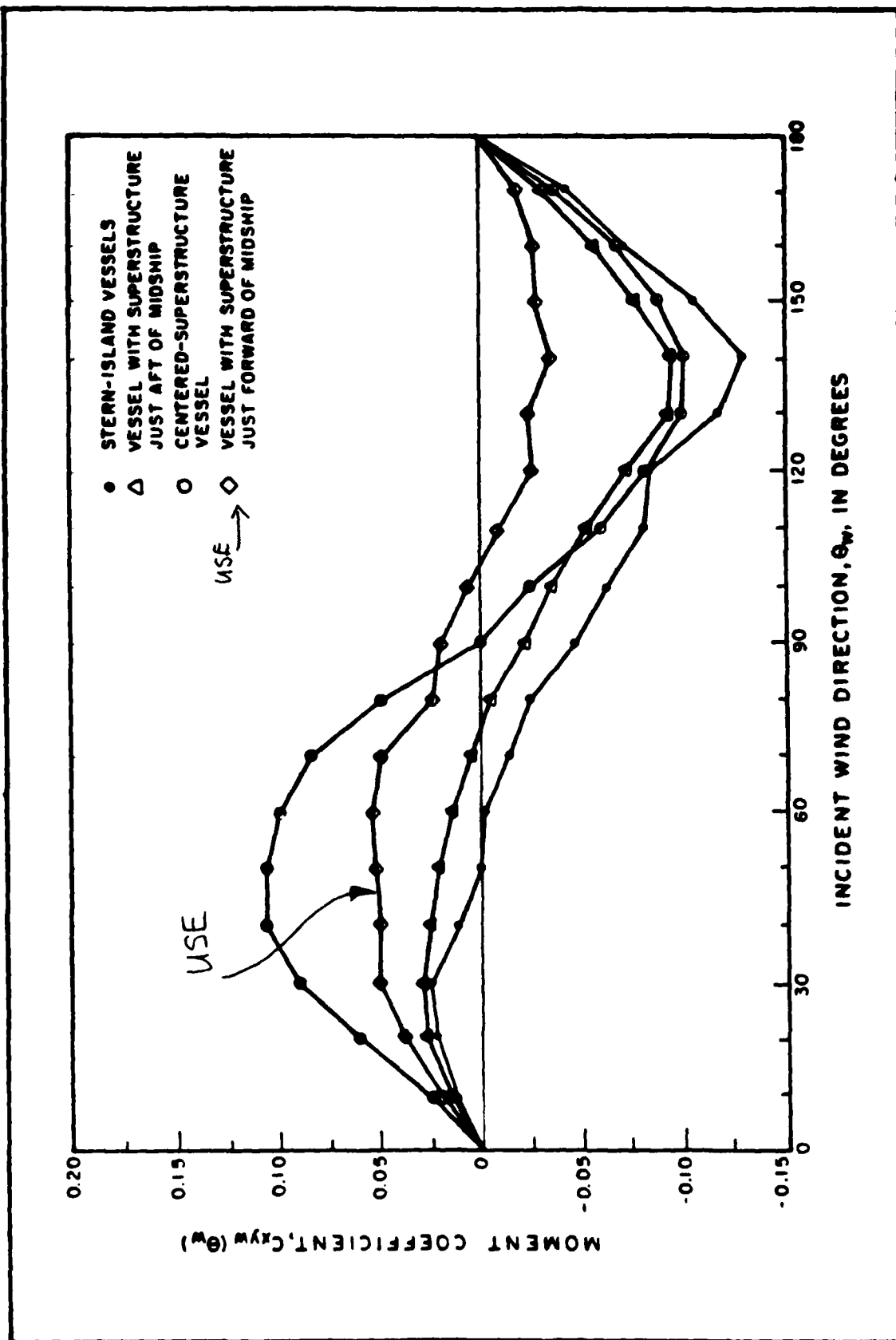


FIGURE 53
Recommended Yaw-Moment Coefficient for Various Vessels According to Superstructure Location

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Calculations for: _____

CURRENT LOADLATERAL

$$F_{yc} = \frac{1}{2}(2) V_c^2 L_{WL} T C_{yc} S_{14} \theta_c \quad \text{Eq (S-35)}$$

$$\phi = 35 D / L_{WL} B T = \frac{35 (110)}{110 (24) 5.5} = 0.27 \quad \text{Eq (S-37)}$$

 \therefore from Fig S8

$$k = 0.7$$

 C_p is unknown; from Table 14 let $C_p \approx 0.6$

$$\therefore C_p L_{WL} / \sqrt{T} = 0.6 (110) / \sqrt{5.5} = 28$$

 \therefore from Fig S7

$$C_{yc1_2} = 2.3$$

$$L_{WL} / B = 110 / 24 = 4.6$$

$$\therefore C_{yc1_\infty} = 0.4 \text{ from Fig S6}$$

$$C_{yc} = C_{yc1_\infty} + (C_{yc1_2} - C_{yc1_\infty}) e^{-k \left(\frac{wd}{T} - 1 \right)}$$

$$= 0.4 + (2.3 - 0.4) e^{-0.7 \left(\frac{50}{5.5} - 1 \right)}$$

$$= 0.407$$

Eq (S-36)

page 5 of 11

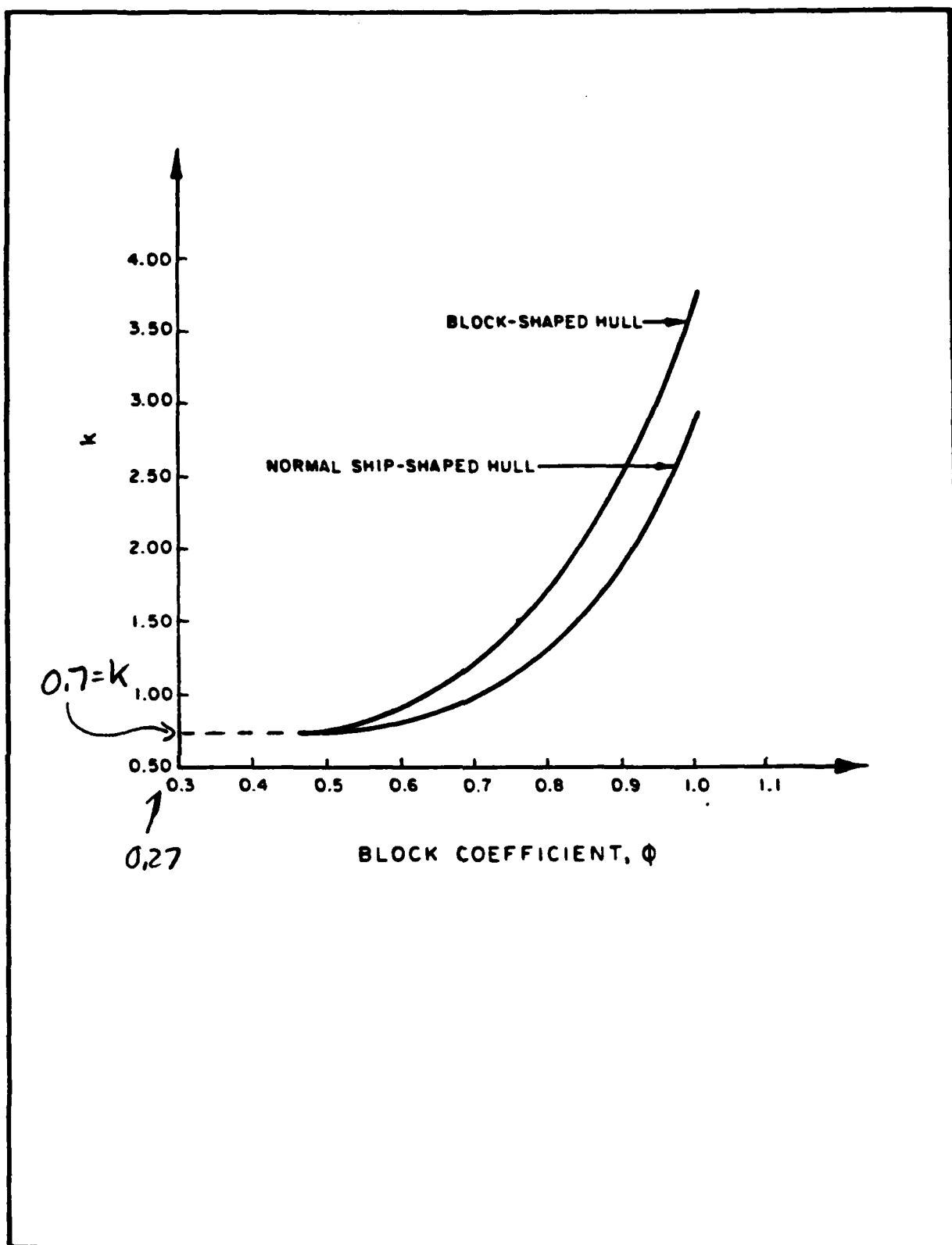


FIGURE 58
 k as a Function of Φ and Vessel Hull Shape

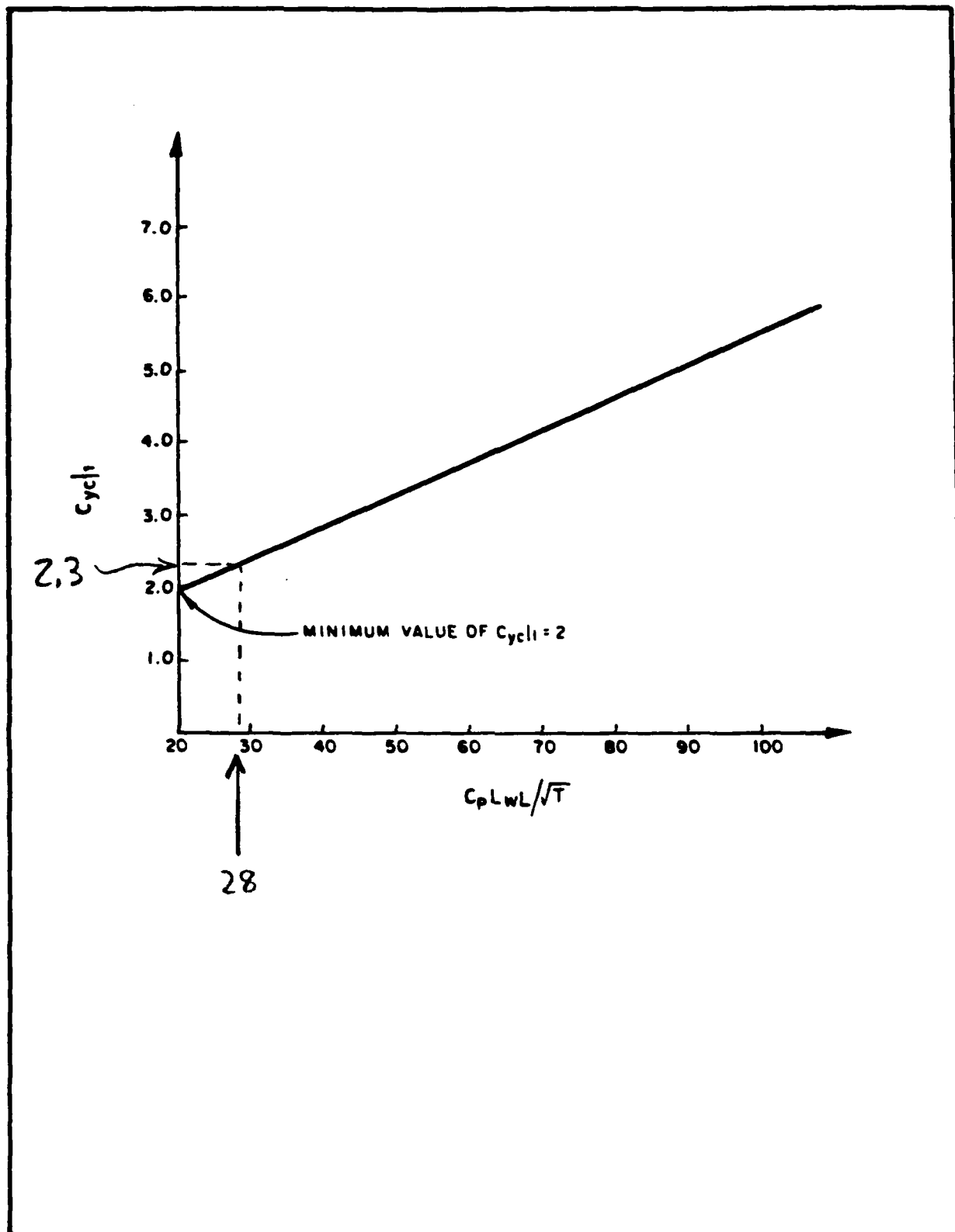


FIGURE 57
 $C_{yc|_1}$ as a Function of $C_p L_W L / \sqrt{T}$

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110'-Foot Vessel

0.2

0.27

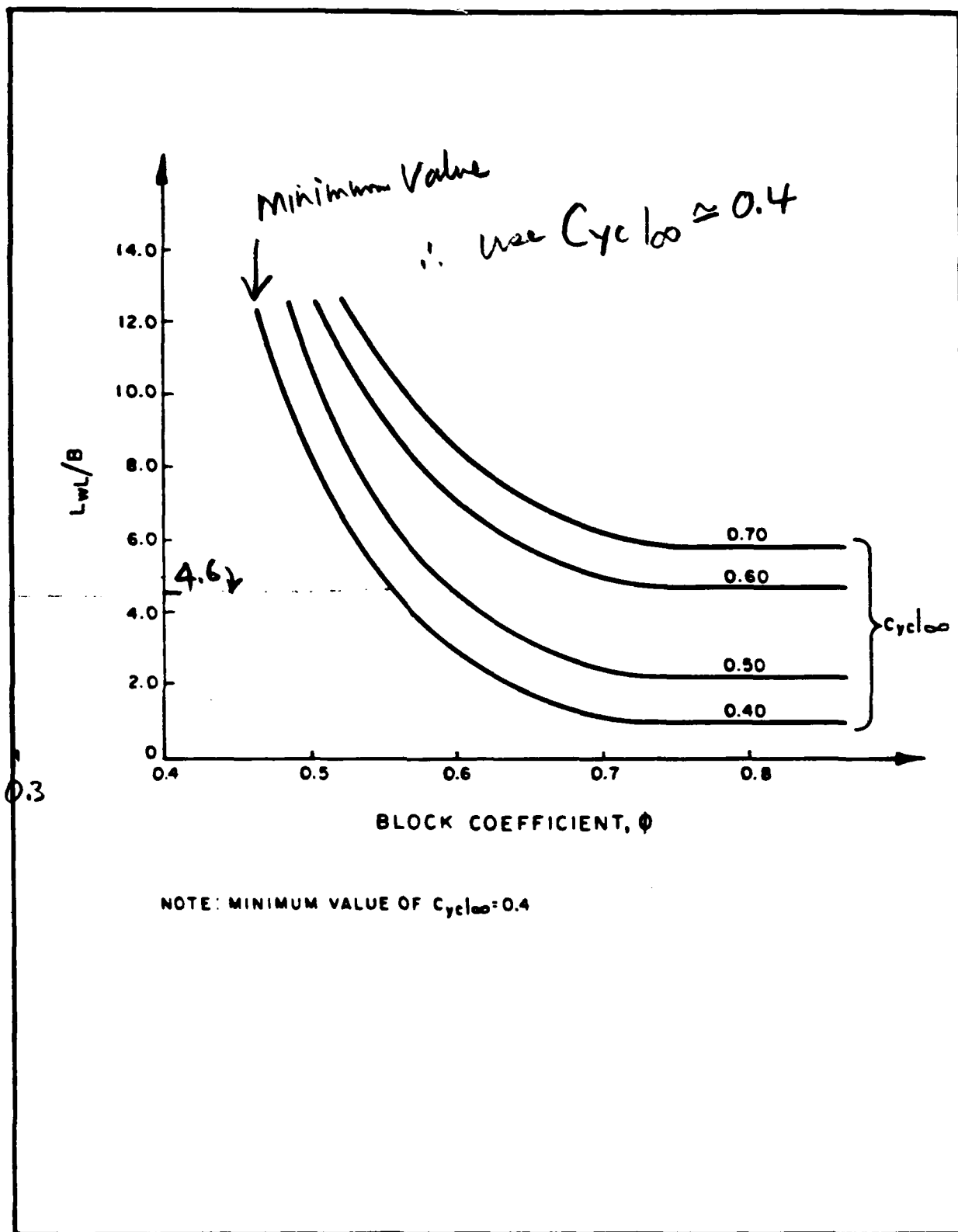


FIGURE 56
 C_{yclo} as a Function of L_{wl}/B and ϕ

8

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Substituting in Eq (S-35)

$$F_{yc} = \frac{1}{2} (2) V_c^2 (110) (5.5) (0.407) \sin \theta_c$$

$$\underline{\underline{F_{yc} = 246.2 V_c^2 \sin \theta_c}}$$

Current LOADEND

$$F_{xform} = -\frac{1}{2} \rho V_c^2 B T C_{xcB} \cos \theta_c \quad \text{Eq (S-41)}$$

$$= -\frac{1}{2} (2) V_c^2 (24) (5.5) (0.1) \cos \theta_c$$

$$= -13.2 V_c^2 \cos \theta_c$$

$$F_{xfri} = -\frac{1}{2} \rho V_c^2 S C_{xca} \cos \theta_c \quad \text{Eq (S-42)}$$

$$\text{where: } R_h = V_c L_{WL} \cos \theta_c / \nu$$

Eq (S-45)

$$= V_c (110) \cos \theta_c / 1.4 \times 10^{-5}$$

$$C_{xca} = 0.075 / (\log R_h - 2)^2 \quad \text{Eq (S-44)}$$

$$S = (1.7 T L_{WL}) + \left(\frac{35 D}{T} \right) \quad \text{Eq (S-43)}$$

$$= 1.7 (5.5) 110' + \frac{35 (110)}{5.5} = 1730 ft^2$$

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$$\therefore F_{x \text{ frie}} = -1730 V_c^2 C_{xca} \cos \theta_c$$

where C_{xca} from Eq (5-44)

$$F_{x \text{ prop}} = -\frac{1}{2} \rho_w V_c^2 A_p C_{\text{prop}} \cos \theta_c$$

Eq (5-46)

$$\text{Let } C_{\text{prop}} \approx 1.0$$

$$A_{\text{TPP}} = \frac{L_w B}{A_R}$$

Eq (5-48)

$$\text{Let } A_R = 100 \text{ (Table 15)}$$

$$\therefore A_{\text{TPP}} = \frac{110(24)}{100} = 26.4$$

$$A_p = \frac{A_{\text{TPP}}}{0.838}$$

Eq (5-47)

$$\therefore A_p = 26.4 / 0.838 = 31.5$$

$$\begin{aligned} F_{x \text{ prop}} &= -\frac{1}{2} (2) V_c^2 (31.5) (1.0) \cos \theta_c \\ &= -31.5 V_c^2 \cos \theta_c \end{aligned}$$

CHESAPEAKE **DIVISION**
Naval Facilities Engineering Command **NDW**
DISCIPLINE

Calcs made by: W. Seelig date: 7/11/85
Calcs ck'd by: [Signature] date: 7/19/85

PROJECT: _____

Station: _____

E S R: _____ Contract: _____

Calculations for: _____

$$F_x = F_{x \text{ form}} + F_{x \text{ fric}} + F_{x \text{ prop}} \quad \text{Eq (S-40)}$$

$$\therefore F_x = -V_c^2 \cos \theta_c (13.2 + 1730 C_{xca} + 31.5)$$

$$\underline{F_x = -V_c^2 \cos \theta_c (44.7 + 1730 C_{xca})}$$

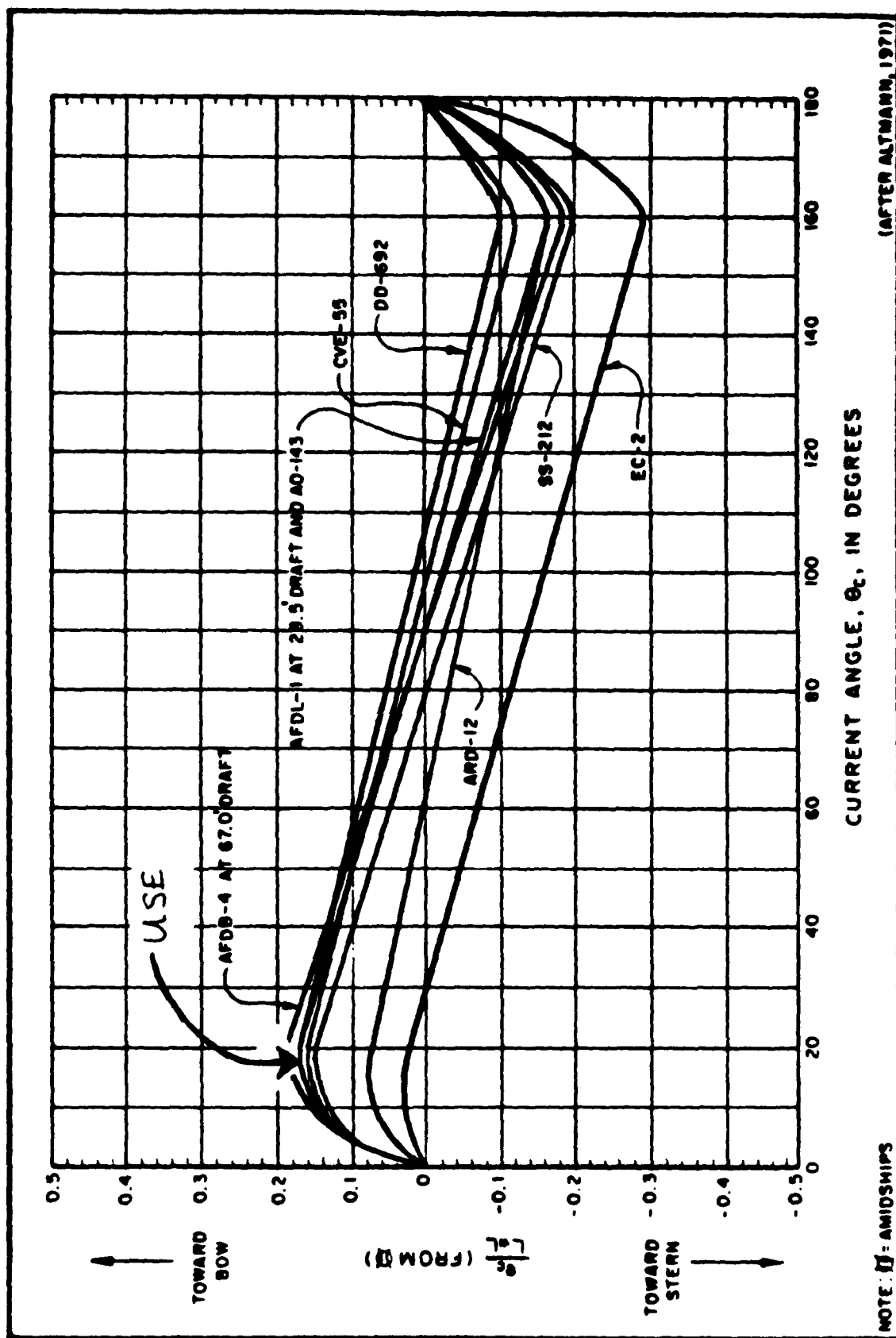
Current Yaw Moment

$$M_{xyc} = F_{yc} \left(\frac{e_c}{L_{WL}} \right) L_{WL} \quad \text{Eq (S-49)}$$

$$\underline{M_{xyc} = F_{yc} \left(\frac{e_c}{L_{WL}} \right) (110)}$$

↑
See Pg 9

↑
Fin 59



NOTE: [] : AMIDSHIPS

CURRENT ANGLE, θ_c , IN DEGREES

(AFTER ALTMANN, 1971)

FIGURE 59
(e_c/L_{wL}) as a Function of Vessel Type and Current Angle

CHESAPEAKE**DIVISION**

Naval Facilities Engineering Command

NDW

PROJECT: Mooring AnalysisStation: Wallace A. S.**DISCIPLINE**

E S R: _____ Contract: _____

Calcs made by: W. Seelig date: 10/24/85Calculations for: Max. Water Wave

Calcs ck'd by: _____ date: _____

Particle Amplitude

(Surge)

Wind Waves

$$\text{Let } T = 8.1 \text{ sec} \\ d = 56 \text{ feet}$$

$$d/L_0 = 56 / (5.12 T^2) = 0.167$$

Orbital motion amplitude of wave is:

$$A = \frac{H}{2} \frac{\cosh(2\pi(z+d)/L)}{\sinh(2\pi d/L)}$$

SFM Eq (2-22)

at surface $z = 0$ wave particle
motion
↓

$$A = \frac{H}{2} \frac{(1.873)}{(1.584)} = 0.6 H$$

0.6H
↔For $h_{\max} = 9.6 \text{ feet}$

$$A_{\max} = 0.6 \times 9.6 = 5.8'$$

APPENDIX B.

ANCHOR SELECTION

Calculations used to select anchors are presented in this appendix. Note that a very conservative approach is taken here for extra safety and based on available inventory.

CHESAPEAKE**DIVISION**

Naval Facilities Engineering Command

NDW

PROJECT: AF MooringsStation: P.I.**DISCIPLINE**

E S R: _____ Contract: _____

Calcs made by: W. Seelig date: 10/25/85Calculations for: Anchor Holding

Calcs ck'd by: _____ date: _____

Stockless Anchors of 6 kips & 14 kips are available, also 13 kips. These anchors have the following (assume 35° fluke angle, See next page):

Anchor Size (kips)	Ultimate Capacity (kips)	Factor of Safety	
		Quasi-Static Load 9.6 kips	Dynamic Peak Load 34 kips
6k	47k	4.9	1.4
13k with Stabilizers	84k	8.8	2.5
14k	92k	9.6	2.7

* recommended

The 13 kip size is recommended because they are available with stabilizers and provide extra safety.

page 1 of _____

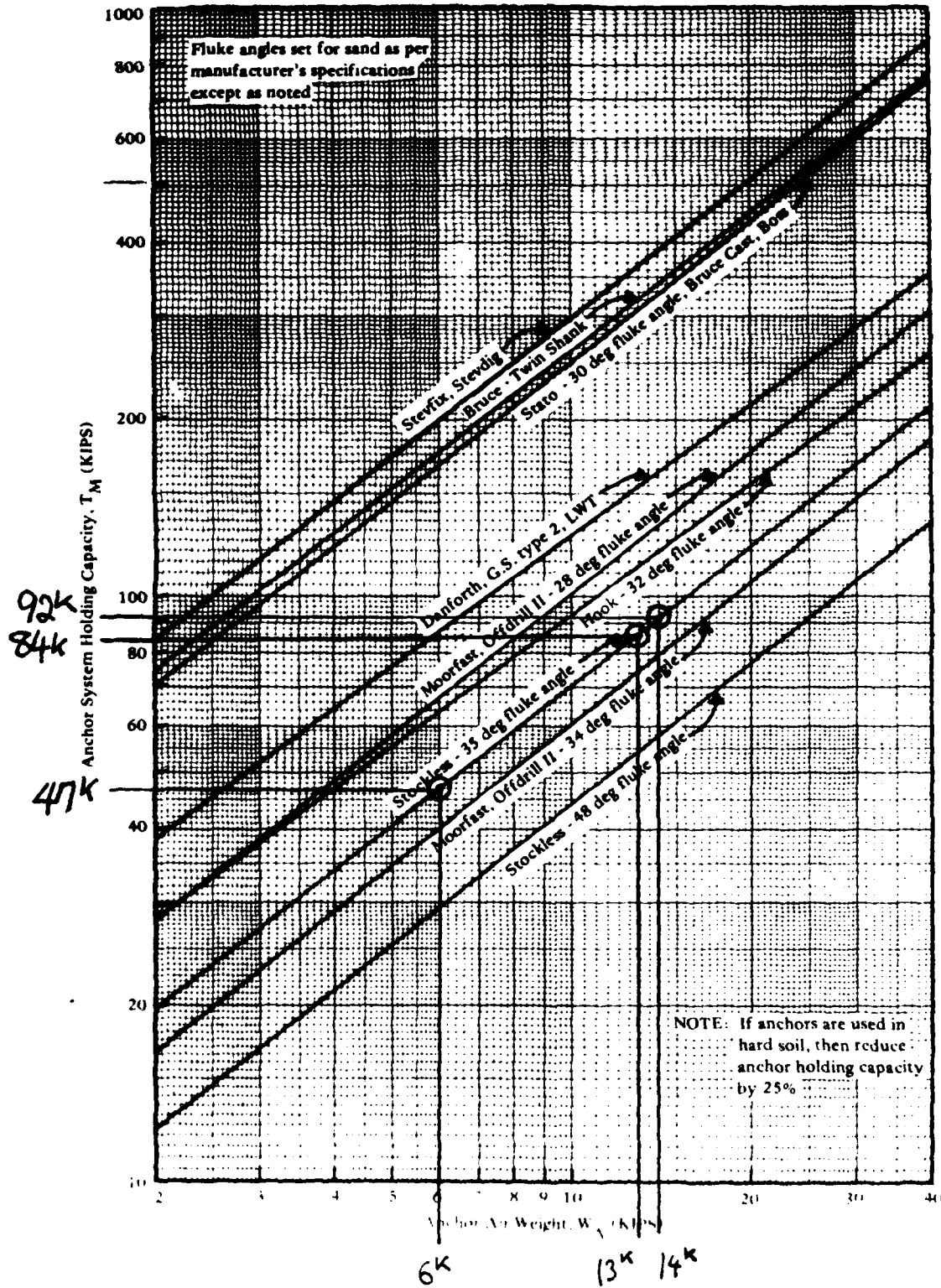
from NCEL

TN NO: N-1688

Jan. 1984

Dense cohesionless soils (sands, gravels)

T_M is the ultimate capacity - Apply factor of safety to determine operating load

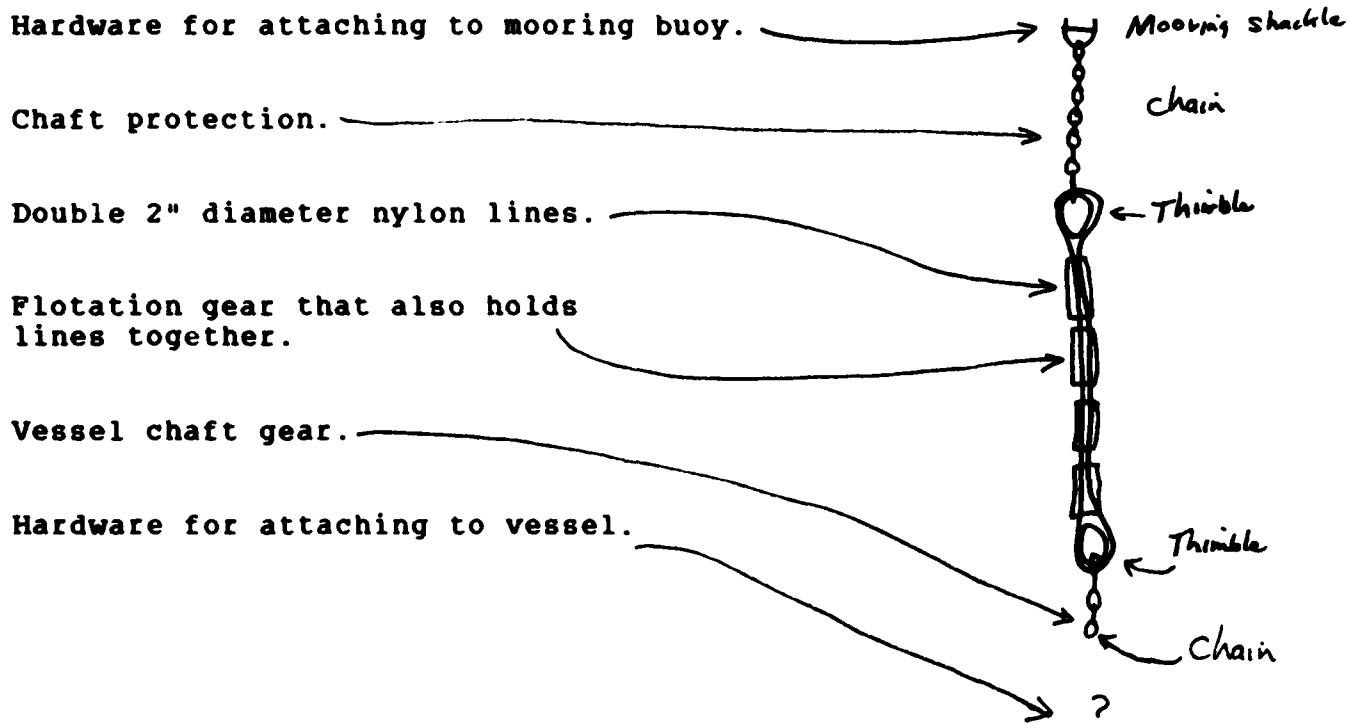


APPENDIX C.

RECOMMENDED HAWSER DESIGN

The recommended hawser concept (to be purchased by the local activity) is presented with notes on use. Detailed hawser design will be given in a separate document, once more information on the new vessels proposed for the area is known.

Each hawser will include:



END

FILMED

3 - 86

DTIC